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**HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII**

Under the joint supervision of the
UNIVERSITY OF HAWAII
and the
UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN NO. 76

**FACTORS AFFECTING THE
CHEMICAL COMPOSITION
OF PASTURE GRASSES**

By
D. W. EDWARDS, Junior Chemist
and
R. A. GOFF, Extension Agent, Island of Hawaii



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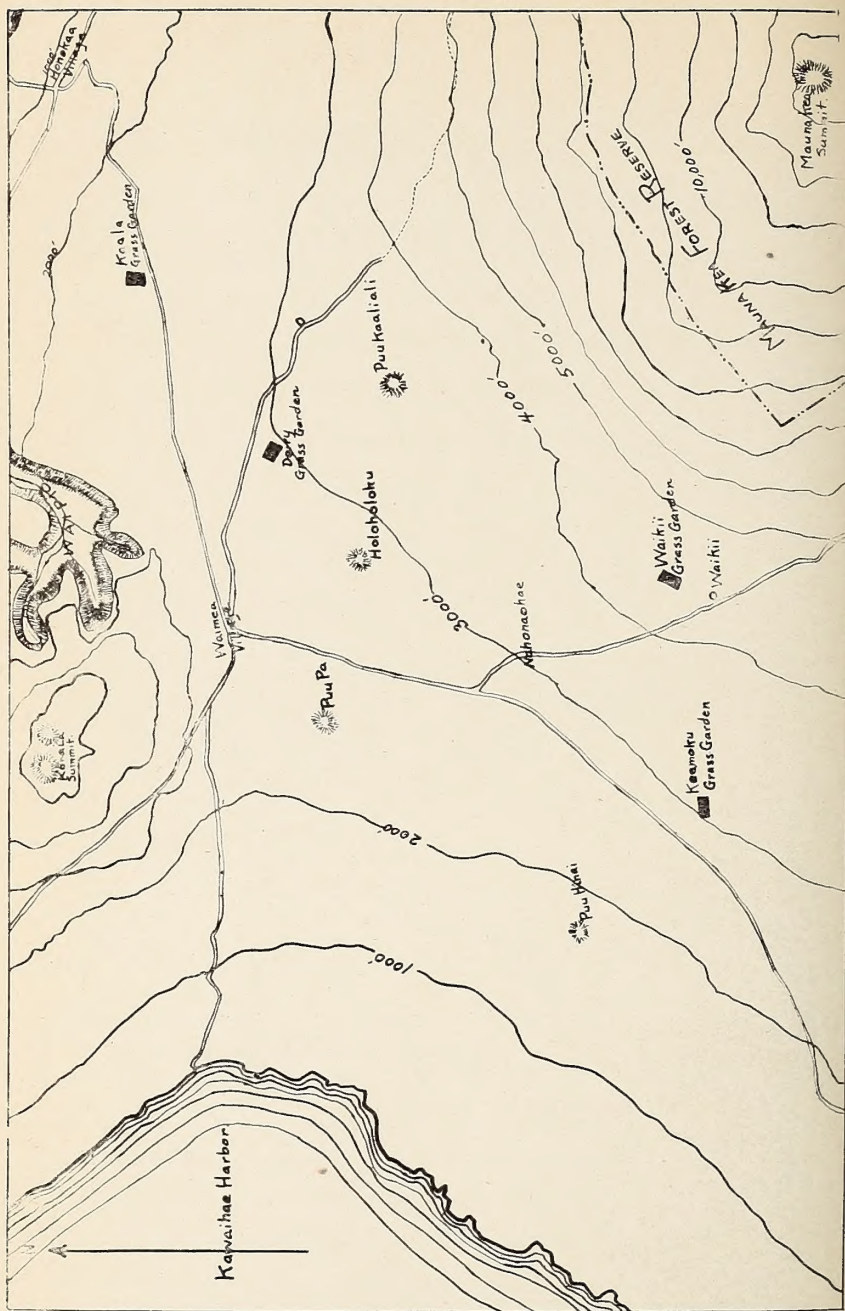
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Scale 1" = 10,000'

Fig. 1—A map of the Waimea district, Island of Hawaii, in which this investigation was conducted.

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CONTENTS

	Page
Introduction	1
Description of Locations of Grass Gardens	3
Plan of Experiment	10
Effect of Different Factors	12
Location	12
Species	15
Relative Effect of Location and Species	19
Relative Effect of Location and Season	21
Discussion	21
Summary	23
Literature Cited	25
Appendix	27

INTRODUCTION¹

The recognition in recent years that mineral deficiencies are prevalent in large areas used for pasturage throughout the world has led to intensive study of this problem. In 1926 a special fund was provided to investigate, within the British Empire, the extent of mineral deficiencies in pastures and to compile all available data regarding their relation to animal nutrition (26²).

¹ The writers are indebted to the Parker Ranch for making possible this investigation, and especially to Mr. A. W. Carter and Mr. G. R. Ewart, III, for valuable information regarding the grass populations and climatological data of the sections of the ranch which were studied.

² Italic numbers in parenthesis refer to Literature Cited, p. 25.

This survey showed the existence in very large areas in British East Africa, Australia and New Zealand of actual mineral deficiency diseases in cattle. Many of the long-used pasture lands of Europe were shown to be seriously lacking in minerals. It was concluded that in many parts of the world the inorganic constituents of the forage are more likely to be limiting factors in growth than protein and energy-producing constituents.

It is stated by Woodman, Blunt and Stewart (32, p. 272) that a grass can be made to vary, when dried, from a feed similar in composition to a high protein concentrate, to one which is but little more nutritious than wheat straw, depending on the stage of maturity at time of cutting. Season, climate, soil and species have also been shown to have a vital effect on quality. Of such importance are they that the analysis of a single sample of grass, or even of a series of samples, without consideration of these factors is practically meaningless. Recognition of the effect of these determinants on the chemical composition of grasses has led, in recent years, to numerous investigations into the management of pastures along such lines as paddocking and rotational grazing (13, 30, 32, 22); cultivating (30); fertilizing (22, 9, 25, 33, 10, 5, 12, 18, 17, 16); supplemental feeding of minerals (4, 20, 19, 23, 8, 14, 3); introducing of new species on the basis of their quality (28, 31, 7); and studying mineral deficiencies of existing pastures (1, 30, 26).

Grass is the chief feed of all *Herbivora* and in most of Hawaii's beef industry, it constitutes the principal feed. The more intensive grazing becomes, the more probable becomes the appearance of some deficiency in quality. The development of high milk-producing and rapid-growing beef strains has imposed greater demands for a high quality of forage than heretofore.

In Hawaii, the fact that there is little evidence of pronounced mineral-deficiency disease in cattle has minimized emphasis of mineral phases. Pasture improvement has been approached chiefly through introduction of new species and these have been judged primarily on the basis of adaptability and palatability rather than on chemical composition. That the great variation of climate, soil and grass population existing on Hawaiian ranges would result in differences in chemical composition was a foregone conclusion. Unpublished data of the authors shows several locations in which minerals may be the limiting factor in growth.

The present experiment is an attempt to measure the difference in quality of grasses under extremes of climate existing on Parker Ranch, Island of Hawaii, and to determine the relative importance of location, grass species and season in affecting

chemical composition. The experiment represents a part of a general study of the adaptability of a number of grass species to varying conditions of climate and soil existent on Parker Ranch. These conditions range from the wet, cool ones of the upper Hamakua Coast, to the dry, seasonal ones of the lee side of the mountains. To a certain extent, the results offer a criterion by which the differences in quality to be expected under similar conditions on the various Islands may be judged.

DESCRIPTION OF LOCATIONS OF GRASS GARDENS

Parker Ranch is located on a plateau lying between Mauna Kea and the Kohala Mountains. The height of these mountains is sufficient to deflect the trade winds through the gap between them, thus causing a wind velocity considerably greater than that of the normal trades. The air, moisture-laden at low elevations and high temperatures, produces a heavy rainfall on the windward slope, increasing to a maximum of approximately 80 inches per year at about 2,500 feet. Beyond this, the rainfall decreases rapidly in progressing across the plateau to the leeward. The strong winds carry the saturated atmosphere in the form of low clouds and driving mists far across the plains so that the district is usually well watered when the annual rainfall is as little as 30 inches. Although there are fairly well-defined seasons, the rainfall throughout the drier summer is usually sufficient for a good growth of grass. Beyond the crest of the plateau, as the altitude gradually decreases, the force of the wind is lessened, and the rainfall from the trade winds becomes almost nil. Precipitation on this leeward slope is very irregular, coming for the most part from the southwest. The rains usually occur in the winter as occasional heavy rains interspersed with long periods of drought.

These factors have a strong influence on grass population. On the windward slope, with its plentiful and generally well-distributed rainfall, long periods of cool, foggy weather with little sunshine sometimes occur. This uniform distribution of rainfall encourages growth of the perennial grasses with a minimum of annuals. Progressing westward, the type of perennials changes and the annual grasses and weeds increase in importance. On the driest of the leeward slopes the perennials become of little importance, while the annual grasses and weeds, which spring up after the rains, form the main bulk of the forage.

Altitude also has an important effect on the grass population. In the wet, windward sections the lowland perennials, like Hilo grass (*Paspalum conjugatum*) and carpet grass (*Axonopus compressus*), predominate in nearly pure stands up to about 3,000 feet. Above this, even though rainfall changes but little, they give way to mixtures of temperate-zone types, such

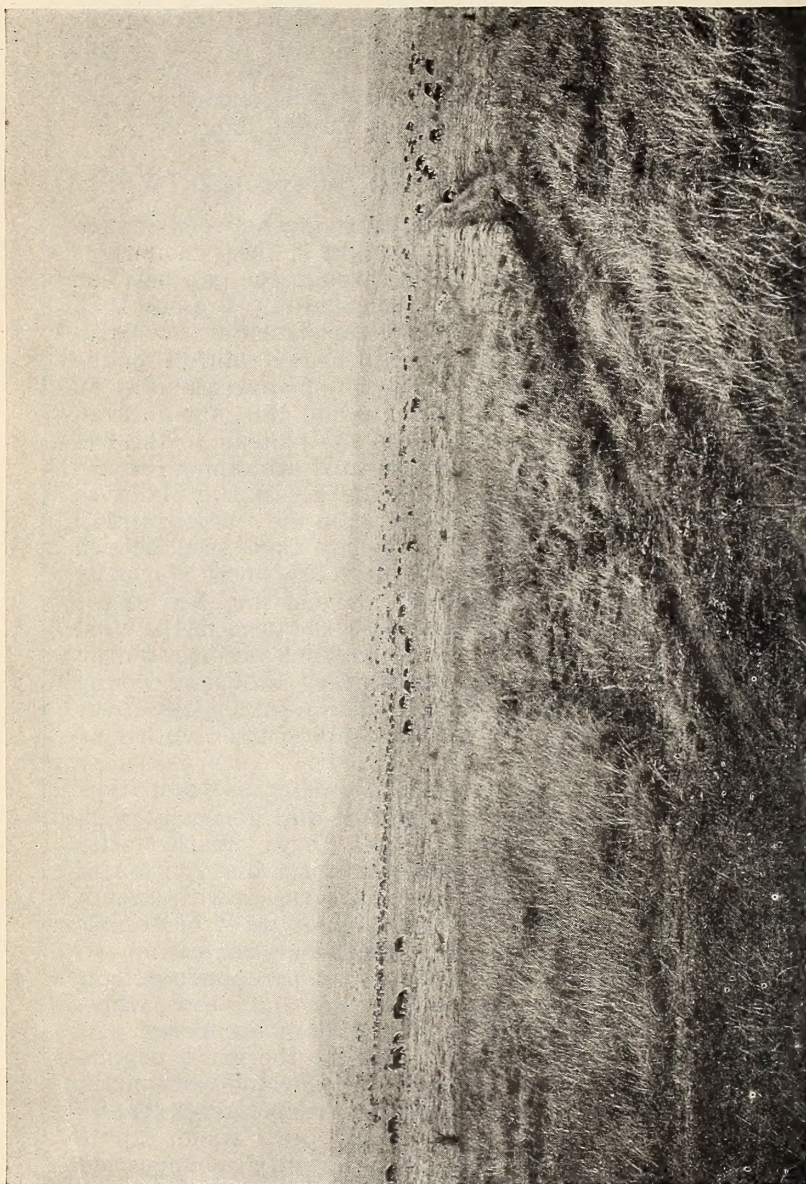


PLATE 1—Dairy section, Parker Ranch, Island of Hawaii. Cinder cones like the one on the left have produced a mantle of volcanic ash over the entire Waimea Plateau. This ash weathers into an excellent fine-textured soil, which supports a vigorous growth of grasses when weather conditions are right. The dairy section is used chiefly for maintenance of breeding cattle.

as Kentucky bluegrass (*Poa pratensis*), orchard grass (*Dactylis glomerata*) and the rye grasses (*Lolium perenne* and *L. multiflorum*).

Following is a brief description of the sections of the ranch in which were located the four grass gardens used in this experiment. (See map, Fig. 1.)

Kaala Section. This section extends across the windward side of the ranch, varying in altitude from 2,000 to 3,000 feet. The climate is windy, the mean annual temperature 65° F.¹ with clouds and foggy weather much of the time, especially in the winter. The normal rainfall is about 46 inches, well distributed throughout the year. The topography is hummocky due to old lava flows overlaid with a mantle of volcanic ash. The soil, which consists chiefly of this ash deposit, is highly hydrated due to continuously humid conditions. It ranges in thickness from a few inches to about two feet. Because of continuous leaching and poor aeration, this soil is of rather low fertility.

Hilo grass makes up a large percentage of the sward, with lesser amounts of carpet grass, *Paspalum* (*Paspalum dilatatum*), known elsewhere as Dallis grass, rattail (*Sporobolus berteroanus*) and brome fescue (*Festuca dertonensis*). Weeds and shrubs are also an important part of the forage, as is evidenced by their copious growth in a rested paddock. They furnish a much needed variety in paddocks where Hilo grass constitutes the only grass of importance. This section is used chiefly for breeding purposes. It is of limited use for fattening but serves as a reserve maintenance pasture during drought when the grass on the remainder of the ranch is dry and withered.

The Kaala grass garden (see map, Fig 1) is located at an elevation of 2,300 feet, well over into the true Hilo grass section. It lies in a depression so that it is protected somewhat from the prevailing winds. The soil is thin and relatively infertile, although a good growth of grass developed in the plowed area. Rainfall and growing conditions were quite normal for this section during the season of 1932-1933, in which the samples to be analyzed were taken, and it was possible to secure a practically complete set of samples for all grasses.

Dairy Section. This section consists of a relatively narrow strip extending across the plateau with an altitude of from 2,700 feet to 4,000 feet and adjoins the Kaala section to the leeward. It is distinctly drier than the latter, with an average of 31 inches of rainfall annually. Although there is more sunshine and less foggy weather than at Kaala, the climate is still windy with considerable fog in the winter and a mean annual temperature of 62° F. The summers are somewhat dry, but in normal years, the rainfall is sufficient for good growth. The

¹ These estimates of the mean annual temperature were obtained through the courtesy of J. F. Voorhees, United States Weather Bureau.



PLATE 2—Grass garden in the dairy section, showing the vigorous growth of the grasses produced during the 60-day period between harvests when ample moisture was present.

topography is gently rolling, with a gradual rise from the central plain toward the mountains on either side. The soil is much more fertile than the more windward soils, due to less leaching and better physical properties. This section is used chiefly to maintain breeding cattle.

The differences in climate and soil give rise to a transition from Hilo grass in Kaala to Bermuda grass (*Capriola dactylon*) in the dairy section. On the windward side of the dairy section, the two grasses exist together, or rather, solid patches of each adjoin one another. Curiously enough, the co-existence of another grass results in much greater quantities of the Hilo grass being eaten than where it exists alone. Further to the west, Bermuda displaces Hilo grass altogether. The distribution of rainfall is such that the grass growth does not dry up in the summer. This results in the so-called tall or long Bermuda growth which has a much lower palatability than the shorter grass in the more seasonal locations, where the heavy top growth dries up periodically, and fresh palatable growth springs up from below.

In addition to Bermuda grass, there are small percentages of bur clover (*Medicago denticulata*), yellow sweet clover (*Melilotus officinalis*) and hop clover (*Trifolium procumbens*). The tall Bermuda effectively chokes out most annuals unless it is heavily stocked or plowed. On the higher slope toward Mauna Kea, at from 3,500 to 4,000 feet, a fine mixture of grasses occurs with the Bermuda. In addition to the above-mentioned, white clover (*Trifolium repens*) appears together with rescue grass (*Bromus unioloides*) (known in Hawaii as brome grass), orchard grass and the rye grasses.

The grass garden in this section is located in the central plain at an elevation of about 3,000 feet. The soil is of good depth (from 1 to 3 feet) and excellent texture. Plowing resulted in a very heavy growth of the various clovers in the spring of the year. The season of 1932 and 1933 was unusual in this section, abnormally low rainfall occurring during the fall and early winter months of 1932 and again in the spring and summer of 1933. The total for the 12-month period from August 1932 to August 1933 was about 15 inches, as compared with a normal of 31 inches. This low rainfall resulted in very poor growth and in a number of instances, no samples were harvested.

Waikii Section. This section lies at an elevation between 4,000 and 5,000 feet. It is sufficiently high and in the lee of Mauna Kea to cause the strong winds, which characterize the lower, windward sections, to be largely absent. There is fog in the more windward parts. Large daily fluctuations in temperature (the mean annual temperature is 59° F.) produce frequent frosts in the winter but sufficient warmth during the day to produce rapid growth of sod. The rainfall ranges from 15 to 25

inches a year. The climate is distinctly seasonal, usually with hot, dry summers. The soil consists of a deep porous layer of very light "talcum powder" ash deposit in the central portion, which thins out into rough, rocky country to the windward.

The seasonal climate of this section, together with the high altitude and frosts have a marked effect on the sward. Bermuda grass, which is the chief perennial grass, dies back during the dry summers and, with the coming of the fall rains, it produces fresh, palatable growth. Natal grass (*Tricholaena rosea*) (known locally as Natal redtop) becomes an important perennial in the leeward and drier part, while Kentucky bluegrass (*Poa pratensis*) is important at the higher levels. Of the annuals, there is a splendid mixture. Rescue grass, mixtures of the rye grasses, bur, hop and yellow sweet clovers make strong growth and seed heavily when the rains come. A common practice on this part of the ranch is to plow up the sod at about 5-year intervals. One crop of corn is grown and the Bermuda sod allowed to gradually re-establish itself. This stirring of the soil produces a marked increase in the amount of these annuals and the total feed produced, while the corn crop usually pays for the plowing.

The Waikii section serves for fattening throughout the year. The animals are turned into the lush growth in the fall and gradually fatten on the maturing grass. Often the final stages of fattening are produced with the completely dry grass which appears to be much more efficacious for this purpose than the very succulent young growth. The high feeding value of this dry grasses results from quick desiccation of the partly mature grass which thus retains its nutritive constituents in the same manner as dry hay. It combines, therefore, an amount of protein sufficient for good growth with the carbohydrates required for fattening. The more windward part of the section is less desirable for fattening and is used chiefly for yearlings.

The grass garden in this section is located at about 4,300 feet altitude and is representative of the best fattening areas on the ranch. The soil is deep, porous and fertile. The 1932-1933 season was drier than normal, the total rainfall from August 1932 to August 1933 being about 15 inches, as compared with a 23-inch average rainfall. No samples could be secured from any of the grasses for August 1933 because of severe drought.

Keamoku Section. Adjoining Waikii to the westward is the Keamoku section. It extends from the 4,000 to about the 2,000 foot level. It has a mild, warm climate, a mean annual temperature of 64° F., and is too far in the lee of Mauna Kea to be touched by the trade winds. Its rainfall comes from the south and west during the winter months, while during the dry summers, local rains, called "naulus," are important in keeping the grasses alive. The total rainfall for the year is about 20 inches,

most of which falls during the winter months. The soil is deep and loose, except in the eastern part where rough lava flows outcrop frequently.

Long, dry periods prevent Bermuda grass from making appreciable growth. Natal grass furnishes the bulk of the feed in most parts. In the upper levels toward Waikii, where rainfall is higher, it is perennial to a considerable degree, making a heavy rank growth. In the drier sections, Natal grass is chiefly an annual; its propensity toward seeding heavily enables it to spring up quickly after the winter rains begin. The heavy seeding clovers, bur, hop and yellow sweet clovers, die down completely during the hot, dry summer and return in the winter. Various weeds, sandbur (*Cenchrus echinatus*), Spanish needles (*Bidens pilosa*) and Kukaipuaa (*Digitaria chinensis* and *D. sanguinalis*) make up a variable but important part of the forage.

The upper part of Keamoku is rated as a first-class fattening section. Like that of Waikii, the forage frequently consists of grass which has been partially or wholly desiccated by sudden droughty conditions. The lower, drier parts of the section are also used for fattening, but the carrying capacity is less.

The grass garden is located in this latter section at an elevation of 3,000 feet. The soil is of fair depth, loose and porous. The 1932-1933 season was normal, the total rainfall for the 12-month period being about 23 inches. There was too little new growth from April to August 1933 to permit sampling any of the grasses during the last two harvests.

Table 1 gives the approximate rainfall for the four grass gardens for the period of August 1, 1932 to August 1, 1933, together with the approximate total for the average year in each locality. Data are only approximate since no rain gauges were located at the grass gardens. The ranch maintains permanent rain gauges at a number of locations spaced at regular intervals and the figures given are interpolations of data from records of two or more nearby permanent rain gauges. Local showers at the grass gardens may thus have vitiated the rainfall data somewhat, particularly in the Waikii and Keamoku Sections.

TABLE 1—Rainfall data for the four grass gardens on Parker Ranch for the period August, 1932 to August, 1933.

	Kaala	Dairy	Waikii	Keamoku
	Inches	Inches	Inches	Inches
August, 1932	1.5	1.1	1.5	1.4
September	1.7	.6	1.4	2.7
October	.3	.2	.8	1.3
November	4.9	.8	1.3	3.7
December	2.3	.2	1.1	1.5
January, 1933	3.0	1.3	1.5	3.1
February	2.2	3.3	2.0	3.4
March	16.5	4.1	1.4	1.9
April	4.7	1.7	2.7	3.2
May	3.5	.6	.9	.7
June	1.2	.1	.1	.0
July	5.0	1.1	.2	.0
Total	46.8	15.1	14.9	22.9
Approximate total for average year ¹	46.0	31.0	23.0	23.0

¹ These figures based on ten-year averages for nearby permanent rain gauges.

PLAN OF EXPERIMENT

The difficulties of experimentation under open range conditions are numerous. Extremes of climate are often encountered. Facilities are lacking for the installation and care of a comprehensive layout. In most localities, stirring the soil or removing the sod results in profuse development of grasses and weeds, so much so that the maintenance of anything approaching a pure stand of the species being studied becomes a costly and time-consuming undertaking.

In the present investigation, an area was fenced off in each of the four locations being studied. The soil was thoroughly plowed and disked and each of the grass species being studied was planted in a plat 10 feet by 18 feet in size. The plats were separated by unplanted strips 3 feet wide. Those grasses that were grown from seed were planted by broadcasting. Where cuttings or root subdivisions were planted, a spacing of 1 foot square was used. The plats were maintained free of extraneous species throughout the experiment. All plantings at the Keamoku, Waikii, and dairy locations were made in February 1932. Those at Kaala were made in April. On June 15 of the same year, the top growth of all grasses was cut and discarded so

that the first samples taken on August 15 would represent a 2-months' growth. Subsequent samples were taken bi-monthly through August 1933, a total of seven harvests.

In the selection of species for a comparison of the effect of location on chemical composition, it was necessary to use those which would grow well in all four locations. This precluded the use of several of the commoner species, such as Hilo grass and carpet grass. It was also desirable that the growth be upright so that the sample could be readily harvested, be ample in amount, relatively free from soil and comprise only the 2-months' growth. There is difficulty in meeting these conditions with the creeping type of growth characteristic of the commoner sod-forming grasses, such as Bermuda grass, carpet grass and Hilo grass.

Five species were selected which combined a maximum of adaptability to the four locations with the greatest accuracy of sampling. These were Rhodes grass (*Chloris gayana*), tall fescue (*Festuca elatior*), Paspalum (*Paspalum dilatatum*), Phalaris (*Phalaris tuberosa*) and Kikuyu (*Pennisetum clandestinum*). The first four are bunch grasses which have relatively coarse, upright stems, and under favorable conditions produce copious amounts of growth. Kikuyu is a creeping grass but the decumbent stems of the new growth are easy to distinguish from the older growth and can be harvested free from contamination with soil.

Numerous experiments (15, 29, 27, 11, 24) in other places have emphasized the effect that stage of maturity has upon chemical composition and the necessity for careful control of this factor in any comparison of the quality of grasses. Under open range conditions, harvesting at a given stage of maturity is scarcely practicable, due to extremes of rainfall and differences in the growth habits of different species. Harvesting at equal time intervals ensures that the growth is of definite age and that all samples harvested at a given time and locality are subjected to the same climatic conditions. Two months was chosen as the interval between cuttings. The original plan of seven harvests at each of the four locations would have yielded 28 samples of each kind of grass. In no case was it possible to get all 28 samples of a given grass, but in several instances the number exceeded 23.

In harvesting the bunch grasses, all the new growth was cut off with sickle or shears close to the crown. In the case of Kikuyu, which is a creeping grass, the sample consisted of the fresh tips of the decumbent stems, which approximated the new growth during the previous 2-month interval.

The samples for chemical analysis were weighed as they were harvested by means of spring scales accurate to within .5 gram, which served as a handy means of determining the green weight

in the field. The grasses were dried and analyzed for moisture, total ash, silica-free ash, protein, lime (CaO) and phosphoric acid (P_2O_5).

It was recognized, at the time of planting, that the general layout of small unreplicated plots would not be suited to measurement of differences between plots with respect to total yields. In such a comparison, soil heterogeneity and other errors incident to the establishment of a uniform sod would invalidate the comparison. In the present study, the comparisons have only been made on the basis of chemical composition. For this purpose, the environmental factors, such as rainfall, altitude, and humidity, together with the general soil characteristics of the section, should predominate over differences in fertility between plots. The subsequent data bear this out. Furthermore, it was concluded that a sequence of samples from unreplicated plots at each of the four locations would give a sounder basis for comparison than would a group of samples of similar size which were all taken at one time from a number of replicates, since it more nearly approaches grazing conditions under which the grass is perennial and grazed throughout the periods of dry weather and slow growth, as well as those of moist weather and optimum growth.

EFFECT OF DIFFERENT FACTORS

The effects of the three factors, location, species, and season, on quality of forage are shown by the analyses of 116 samples. They comprise five species grown at four different locations during seven 2-month intervals. These comparisons deal only with crude protein, lime and phosphoric acid. Moisture, total ash and silica-free ash were also determined but failed to show significant differences or trends and are therefore omitted. The analytical data from which the subsequent comparisons are taken are given in the appendix, p. 27.

LOCATION

The four locations have been compared on the basis of the analysis of five species, namely, Rhodes grass, tall fescue, *Paspalum*, Kikuyu, and *Phalaris*. Obviously, "location," as used here, serves to designate a particular set of conditions which make up the environment at that place.

This comparison has been made by the method known as "pairing." For example, in comparing the Waikii grass garden with the Dairy grass garden, the protein content of each sample of each grass species harvested at Waikii was paired with the protein content of the same species harvested at the same time at the Dairy, and the difference determined. These comparisons were repeated between each two grass gardens, using all available "pairs." Incomplete data necessitated the omission of some of the "pairings" in this comparison. For example, if Rhodes

grass was not harvested at Waikii in August of 1932 but was at the Dairy, it is quite obvious that no "pair" existed, and this analysis of the Dairy section sample was not used. However, this analysis, i.e., Rhodes grass-Dairy section-August, 1932 could be paired with Rhodes grass-Kaala-August, 1932 and was therefore useful in this comparison. The average protein content of all samples from Waikii, which were used in the Waikii-Dairy comparison, is not, therefore, the same as the average used in the Waikii-Kaala comparison.

This method of pairing compares each two locations by means of 35 individual comparisons (if all pairs are available, i.e., 5 grasses growing at each location for 7 harvests). The differences in composition, due to location, are obviously due to a summation of all the environmental factors of climate and soil. From a practical standpoint, it shows the difference in quality of grasses grown at each location, regardless of its cause.

The mean difference between the members of each pair was determined and divided by the standard deviation of the differences. This is Student's "Z" value, which, when referred to his tables, gives the odds against the difference noted being due to chance alone. For additional details of the method and the table used, the reader is referred to a treatise (21) on Student's method.

For the sake of brevity, the calculations resulting from the pairings of the analyses of grasses are omitted. The results of the comparisons of locations are summarized in Table 2.

TABLE 2—Effect of location on the protein, lime and phosphoric acid content of Grasses.¹

(Results expressed as percent of dry weight.)

(Percentage given at left is for location given in left-hand column, that given at right is for location given at top of the column in which number appears.)

	WAIKII	DAIRY	KAALA	KEAMOKU
PROTEIN (N x 6.25)				
Waikii	—	10.8 — 11.4	11.0*—11.6	11.9*—12.2
Dairy	11.4*—10.8 ²	—	11.1*—11.5	12.1*—11.8
Kaala	11.6*—11.0	11.5*—11.1	—	12.0*—12.0
Keamoku	12.2*—11.9	11.8*—12.1	12.0*—12.0	—
LIME (CaO)				
Waikii	—	1.06 — .96	1.05 — .63	1.11 — .99
Dairy	.96 — 1.06	—	.95 — .66	1.00*— .95
Kaala	.63 — 1.05	.66 — .95	—	.66 — .99
Keamoku	.99 — 1.11	.95*—1.00	.99 — .66	—
PHOSPHORIC ACID (P ₂ O ₅)				
Waikii	—	1.09 — .74	1.08 — .49	1.13 — .34
Dairy	.74 — 1.09	—	.76 — .49	.71 — .33
Kaala	.49 — 1.08	.49 — .76	—	.49 — .33
Keamoku	.34 — 1.13	.33 — .71	.33 — .49	—

¹ The method of statistical analysis used is that of Student for determining the validity of differences in paired results.

* indicates that by the method of statistical analysis used; the differences between these averages have been adjudged too small to be of assured significance.

By means of the table, it is possible to compare each location with each other location, with respect to protein, lime and phosphoric acid. For example, it is desired to compare the lime content of forage from Waikii with that from each of the other locations. Find "Waikii" at the left-hand side of the page under "Lime" and read to the right. It is apparent that Waikii is greater than Dairy (Waikii 1.06 per cent CaO—dairy .96 per cent CaO); greater than Kaala (Waikii 1.05 per cent CaO—Kaala .63 per cent CaO); and greater than Keamoku (Waikii 1.11 per cent CaO—Keamoku .99 per cent CaO). In a like manner, the locations may be evaluated with respect to protein and phosphoric acid.

From Table 2, it appears that in no case are there odds of sufficient magnitude to warrant the conclusion that the protein content of forage from one plot is significantly greater than that from another. In fact, it is remarkable that the protein content of forage from each of four locations should average so nearly

the same when those four location differ so widely in climate and apparent fertility. (Highest average value 12.09 per cent; lowest 10.77 per cent.) In view of the well recognized effect which stage of maturity (15, 29, 27, 10, 24) has upon percent of protein, this lack of variation constitutes a gratifying proof that the marked differences between locations in the two other constituents, lime and phosphoric acid, were not due to differences in stage of maturity of the grasses when harvested. It should be emphasized that the foregoing values of protein, lime and phosphoric acid are average values. The fluctuations in percent of protein, due to species and to season, were considerable as is evidenced by subsequent data.

The lime content of forage from three of these locations shows slight though statistically significant variation from one to the other, those from Waikii being highest but closely followed by Dairy and Keamoku. Kaala, however, yields forage very much lower in lime than the others. This might be anticipated because of the leaching effect upon the soil of the higher annual rainfall at this location, normally almost double that at any of the other plots.

With respect to phosphoric acid, the differences between these four locations are very large, forage from Waikii with the average value of 1.10 per cent P_2O_5 being more than three times that of Keamoku with an average value of .33 per cent P_2O_5 .

This series of comparisons has been summarized in Fig. 2. The values for Waikii are taken as the standard and each constituent is expressed as percent of the same constituent at Waikii.

SPECIES

Although the experimental set-up used in this investigation was not as well adapted to a measurement of varietal differences between the grasses used, as it was to showing the effect of environment; nevertheless, much data of an indicative nature were accumulated.

In the determination of the effect of species, new "pairs" are set up so as to afford a comparison of the five species—Rhodes, Tall fescue, Paspalum, Kikuyu and Phalaris. In this case the pairs consist of each two of the grass species grown in the same location and harvested at the same time. The pairs of all four locations are grouped together. The effect of species is shown in Table 3. The use of this table may be illustrated by the following example: If it is desired to compare the protein content of Phalaris with each of the others, find Phalaris in the left-hand column and read across. It is apparent that it excels Rhodes by the difference between 13.9 per cent and 8.8 per cent; Tall fescue by the difference between 14.1 per cent and 12.3 per cent; Paspalum by the difference between 14.1 per cent and 10.1 per cent protein.

PROTEIN (N x 6.25)

LIME (CaO)

PHOSPHORIC ACID (P₂O₅)

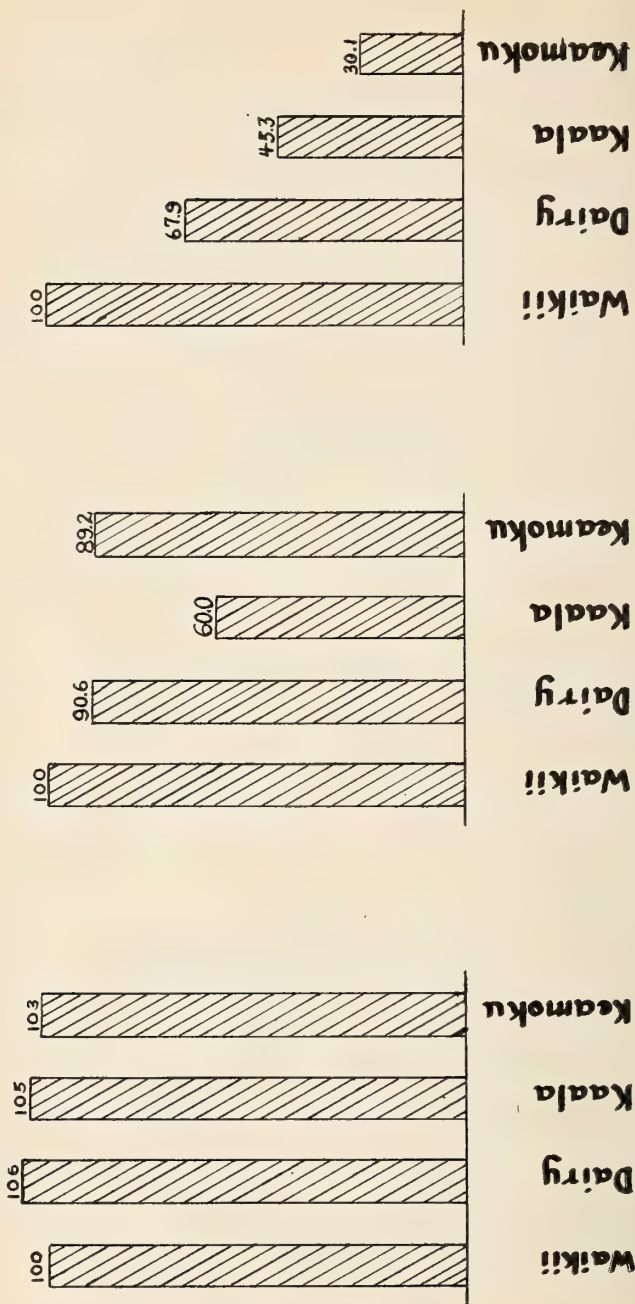


Fig. 2—Effect of location on the protein, lime and phosphoric acid content of grasses.
(Each constituent is compared to that of Waikii as 100 percent.)

TABLE 3—Effect of grass species on chemical composition of forage.¹
 (Results expressed as percent of dry weight.)
 (Percentage given at left is for grass species in left-hand column; that given at right is for species at top.)

	Rhodes	Tall fescue	Paspalum	Kikuyu	Phalaris
PROTEIN (N x 6.25)					
Rhodes	—	8.8 —12.1	8.8 —11.3	8.8 —10.1	8.8 —13.9
Tall Fescue	12.1 — 8.8	—	12.1 —10.9	12.2 —10.1	12.3 —14.1
Paspalum	11.3 — 8.8	10.9 —12.1	—	10.9*—10.1 ²	10.9 —14.1
Kikuyu	10.1 — 8.8	10.1 —12.2	10.1*—10.9	—	10.1 —14.1
Phalaris	13.9 — 8.8	14.1 —12.3	14.1 —10.9	14.1 —10.1	—
LIME (CaO)					
Rhodes	—	.96 — .77	.93*— .89	.96*— .93	.96 — .71
Tall Fescue	.77 — .96	—	.82 — .95	.84 — .98	.82 — .76
Paspalum	.89*— .93	.95 — .82	—	.95*— .97	.94 — .74
Kikuyu	.93*— .96	.98 — .84	.97*— .95	—	.96 — .76
Phalaris	.71 — .96	.76 — .82	.74 — .94	.76 — .96	—
PHOSPHORIC ACID (P₂O₅)					
Rhodes	—	.65*— .57	.61 — .48	.65*— .67	.65*— .66
Tall Fescue	.57*— .65	—	.58 — .50	.64 — .77	.66 — .75
Paspalum	.48 — .61	.50 — .58	—	.50 — .74	.52 — .72
Kikuyu	.67*— .65	.77 — .64	.74 — .50	—	.78*— .75
Phalaris	.66*— .65	.75 — .66	.72 — .52	.75*— .78	—

¹ The method of statistical analysis used is that of Student for determining the validity of differences in paired results.

² Indicates that by the method of statistical analysis used, the differences between these averages have been adjudged too small to be of assured significance.

Consideration of the above table indicates that considerable differences do exist between species in a majority of the comparisons. These differences are most marked in protein and least in phosphorus. They are doubtless largely due to the differing rates at which these species attain maturity. It should be emphasized again that these comparisons do not purport to show which is the best grass but rather to point out the differences, regardless of their causes.

The five species may be rated according to their content of protein, lime and phosphoric acid as follows, No. 1 containing the most in each rating:

Protein (N x 6.25)	Lime (CaO)	Phosphoric Acid (P ₂ O ₅)
1. Phalaris tuberosa	1. Rhodes grass	1. Kikuyu
2. Tall fescue	2. Kikuyu	2. Phalaris tuberosa
3. Paspalum dilatatum	3. Paspalum dilatatum	3. Rhodes grass
4. Kikuyu	4. Tall fescue	4. Tall fescue
5. Rhodes grass	5. Phalaris tuberosa	5. Paspalum dilatatum

RHODES T.FESCUE PASPALUM KIKUYU PHALARIS

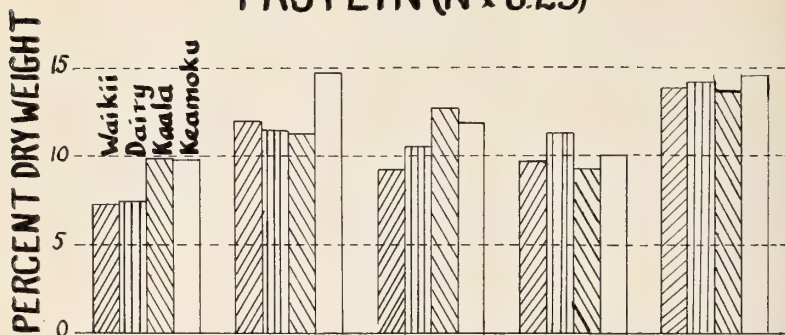
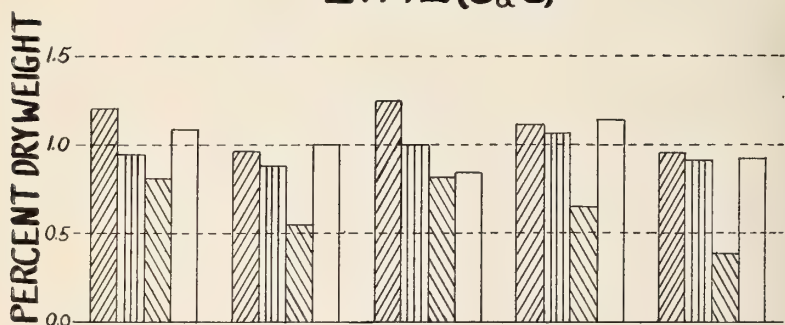
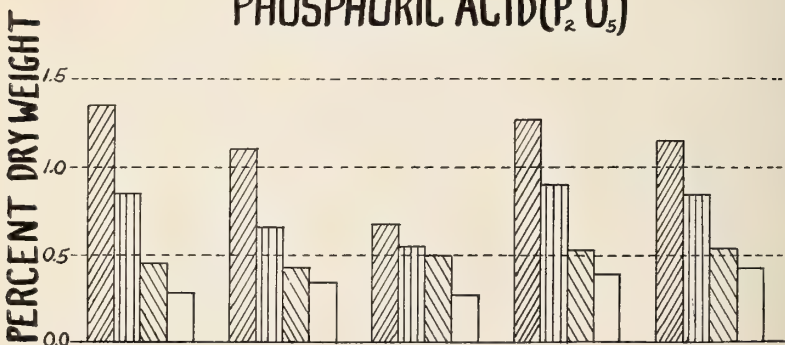
PROTEIN ($N \times 6.25$)LIME (C_aO)PHOSPHORIC ACID (P_2O_5)

Fig. 3—Relative effect of species and location on the chemical composition of grasses.
(Results are the averages of all harvests of each grass species at each location.)

The rating of the grasses in the descending order of each constituent brings out the fact that, between the species compared, the rankings of protein and lime are the inverse of one another, while phosphoric acid bears no constant relation to either of the other constituents.

RELATIVE EFFECT OF LOCATION AND SPECIES

The relative effect of location and species is shown in Fig. 3. The mean values for each species at each location are given. These values represent the numerical average of all the harvests of a grass at each location and thus mask the effect of season.

From the preceding figure, it is apparent that the different species yield a greater variation in percent of protein at a given location than is exhibited by any one species among the four locations. The maximum variation among locations for a single species is shown by *Paspalum*, 9.05 per cent at Waikii to 12.69 per cent at Kaala, a difference of 3.64 per cent. The maximum difference noted between species at one location occurred in the Dairy section where *Rhodes* had an average of 7.55 per cent protein and *Phalaris* an average of 14.29 per cent, a difference of 6.74 per cent. This difference between species is nearly double the maximum difference due to locations and is moreover more consistent. Therefore, of the two factors, location and species, species was of greater importance than location in determining the percent of protein.

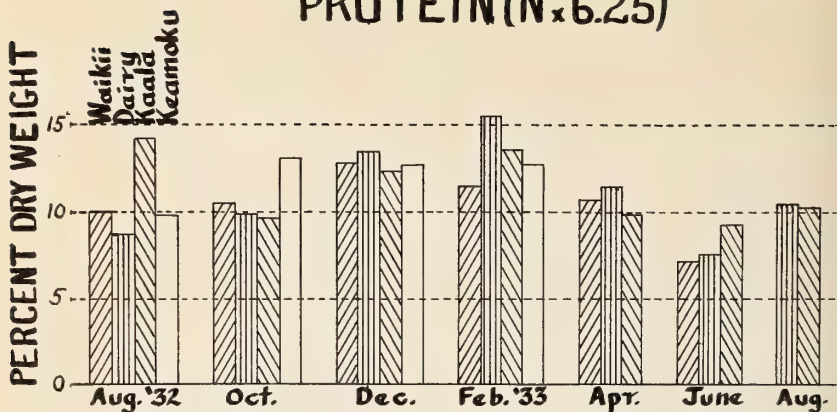
In the case of lime (CaO), the greatest difference between two species occurred at Kaala where *Rhodes* and *Paspalum* each averaged .81 per cent and *Phalaris* only .39 per cent, a difference of .42 per cent. The greatest difference between two locations, as judged by a single species, is shown by *Phalaris*, which averaged .94 per cent lime (CaO) at Waikii and only .39 per cent at Kaala, a difference of .55 per cent. Location was more important than species in determining the percent of lime.

Phosphoric acid content of all species varies between wide limits for the different locations, the maximum difference due to location being shown by *Rhodes* grass, which averages 1.36 per cent (P_2O_5) at Waikii and only .29 per cent (P_2O_5) at Keamoku, a difference of 1.07 per cent. The greatest variation between species at a given location was at Waikii where *Rhodes* grass averaged 1.36 per cent (P_2O_5) a difference of .68 per cent.

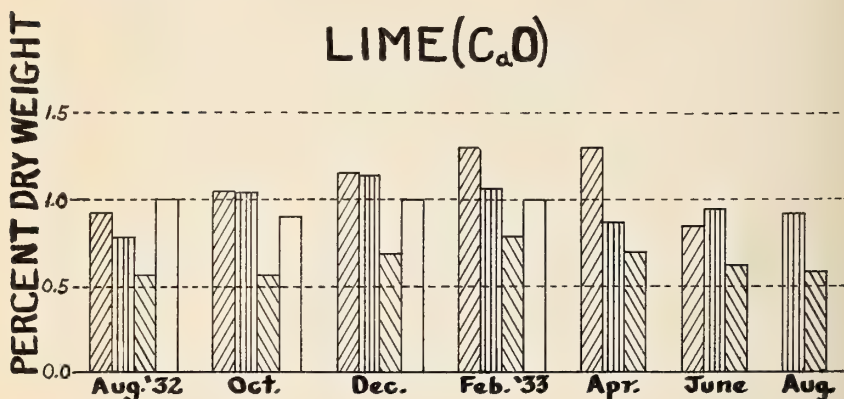
From the foregoing it is apparent that protein was more affected by species¹ than by location, but that location was dominant over species in determining the percent of lime and phosphoric acid.

¹ For an exact comparison of species, Table 3 should be used since it takes into account the seasonal fluctuations and is based upon the results of "pairing" rather than on simple numerical averages.

PROTEIN (N $\times$ 6.25)



LIME (CaO)



PHOSPHORIC ACID

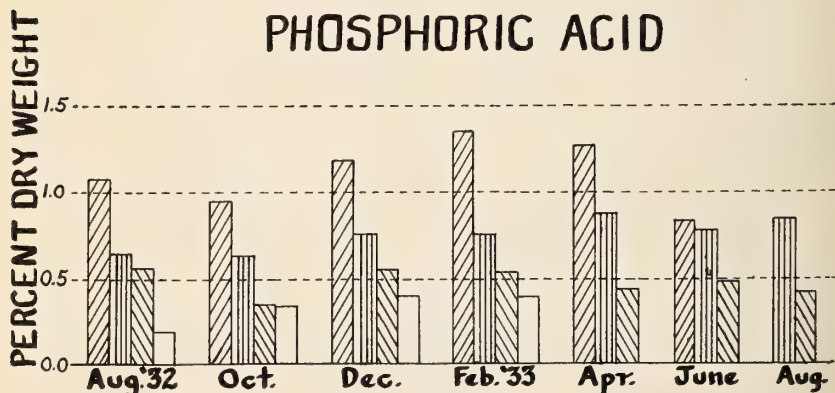


Fig. 4—Relative effect of location and season on the chemical composition of grasses. (Results are the average of five species.)

RELATIVE EFFECT OF LOCATION AND SEASON

In the previous sections, the effect of season on the chemical composition has been masked since only averages have been dealt with. Figure 4 shows the changes due to seasons and location. The analyses of the five grasses at the four locations are regrouped so that each value represents the average of the five species at each location for a given harvest. Some of the blocks are missing since not all five grasses could be harvested because of dry weather.

There is a distinct, though somewhat irregular, seasonal trend apparent at each location. This is more apparent at some locations than at others. All locations seem to have reached their maximum percentages of protein, lime and phosphoric acid during mid-winter when yields were at a minimum. The positive correlation between the fluctuations of protein and phosphoric acid, which is apparent here, is often reported by other investigators (2, p. 229; 6, p. 753; 1, p. 7). The trend in lime content here appears to follow that of protein and phosphoric acid, being highest at most plots in mid-winter and decreasing throughout the spring and early summer. Other investigators (1, p. 7) have found that lime increased with dry and decreased with wet weather.

As to the relative effects of season and location, it appears that season was dominant in determining the percent of protein but that location had a greater effect than season upon the percentages of lime and phosphoric acid.

DISCUSSION

The results of the experiment here reported show rather conclusively the relative effect of the three factors—location, species and season—on chemical composition of grasses. Location is dominant over species and season with respect to the mineral constituents, calcium and phosphorus. It has, however, no consistent effect on protein (Fig. 2). On the other hand, species and season have a pronounced effect on protein and also on calcium and phosphorus.

When these results are considered, the conditions of the experiment should be kept in mind. All the samples represent fresh growth only. Where dry weather prevented new growth from developing during the 2-month interval between harvests, no samples were taken. The results do not take into account the amount of forage produced at different locations in different seasons or by different species. One sample may represent as little as 1 pound green weight from a plat, while another might represent as much as 60 pounds.

The conditions set up are necessarily arbitrary. For example,

the 2-month interval between harvests resulted in an often-times stemmy growth of Rhodes grass compared with the other four species. A shorter interval, which would have given a more leafy sample, might have enhanced the relative value of Rhodes grass. Also if an amount of moisture sufficient for growth was not present at the beginning of each 2-month interval, the growth harvested may actually have been much less than two months old. Only five grasses were considered. It is quite possible that inclusion of other species, particularly legumes and various weeds, in the comparison might affect the general conclusions as to the relative effect of species. Moreover, the five species considered did not represent the actual species present in the sod, since it was necessary to have the same species growing in all four locations.

It was unfortunate that the season of 1932-1933 was abnormally dry at the Dairy and Waikii sections. However, it is scarcely conceivable that this would affect the essential conclusions drawn, since the same general relationship between sections held during periods when there was ample moisture as well as the dry periods. For example, during the months of August to December, growing conditions were unusually favorable at Keamoku, all grasses producing heavy yields, and yet the phosphorus content of the grasses was as uniformly low with respect to the other sections as during the subsequent months when the growth was very stunted due to drought. The general conclusion seems incontrovertible that location is dominant in its effect on the percentage of calcium and phosphorus in grass and that in the present experiment the differences noted were not due to unusual season. It is interesting to note that there was nothing in the appearance of the grasses that would indicate such marked differences in mineral content. In all cases the growth was vigorous and normal in appearance whenever adequate moisture was available.

With respect to species, the data show marked differences for all three constituents. The differences noted are smaller in most cases than fluctuations which can be found with the same species at the different locations or at different seasons of the year. The differences among the species were great in a majority of cases, especially with respect to protein, where 9 out of 10 comparisons produced significant differences. Obviously, with the inclusion of different types of forage, such as legumes, the differences in nutritive constituents would be much greater. In comparison of species, it should be especially emphasized that the data are to be considered only for the conditions of the experiment.

The translation of results of chemical analysis of forage into terms of production of beef or dairy products is always difficult. The reasons for this are numerous. Unless a single species and

regular rotation are used, it is difficult to determine what the animal eats. Normally it prefers a variety, which explains the fact that a less palatable grass, such as Hilo grass or rattail, is eaten in mixed swards where in pure stands it is scarcely touched. In practically all ranges, annual grasses, weeds and shrubs form an extremely variable but oftentimes an important and highly nutritious part of the animal diet. In addition, the direct effect of climate on the animal is apparent not only in its general health but in the amount of feed which it consumes.

In the experiment here reported, all these uncontrolled factors were present to no small degree. The sheltered, seasonal climates of the Waikii and Keamoku sections are in very marked contrast to the cool, windy humid climates of the Kaala and the Dairy sections. The grazing methods are also different. In the leeward sections mature and often dry grasses comprise the feed, while in the windward sections the forage is mostly green and succulent.

Parker Ranch reports that there is no evidence that cattle in the Keamoku section suffer from lack of phosphates. Given sufficient rainfall, fattening is rapid. It seems evident that minerals are not the limiting factor of growth of the animal in any of the sections studied and that the superiority of the leeward sections for fattening is not due to inherent differences in mineral constituents but rather to the botanical nature of the sward resulting from the seasonal climate and the better adaptability of the animal to these conditions.

Although a review of the literature available on the subject of mineral deficiencies in cattle would be entirely too voluminous to present here, it is of interest to note that the average P_2O_5 content of forage from Keamoku is lower than all but one of those reported by Archibald (1) for some Massachusetts pastures and lower than all but two of those he quotes from other places.

Orr (26) points out that a good pasture will contain approximately 1.1 percent lime (CaO) and .7 percent phosphoric acid (P_2O_5) (as percent of air-dry grass).

Becker et al (3) give data to show that approximately .5 percent lime (CaO) and .3 percent phosphoric acid (P_2O_5) (as percent of air-dry grass), form the dividing line below which deficiency symptoms appear and above which they are absent. If the green foliage from the four areas studied in this investigation be judged on this basis, Keamoku only would appear to be near the borderline of mineral deficiency.

SUMMARY

The relative effect of three factors—location, species and season—on the chemical composition of grasses was studied in different sections on Parker Ranch, Island of Hawaii. Five

grasses, Rhodes grass (*Chloris gayana*), tall fescue (*Festuca elatior*), Paspalum (*Paspalum dilatatum*), Phalaris (*Phalaris tuberosa*) and Kikuyu (*Pennisetum clandestinum*) were planted in each of four locations. Samples for chemical analysis were taken at bi-monthly intervals for a period of 14 months. A total of 116 samples was analyzed. By the "pairing" method of statistical analysis, the effect of location, species and season on the protein, calcium and phosphorus content of the grasses was determined.

The results show that location has a strong influence on the absorption of phosphorus and calcium. The phosphorus content in the best section was three times that in the poorest section. The calcium content in the best section was 1.7 times that of the poorest. The average percents of protein of all grasses were practically identical for the four locations. While the lowest percentages of phosphorus occurred in the dry, leeward section, lack of moisture did not appear to be the primary cause since the percentage was equally low during periods of ample rainfall and vigorous growth. Low calcium and phosphorus in the forage was found in the wet, windward section.

Composition varied with species, the effect being the greatest in the case of protein. Of the five species studied, 9 out of 10 comparisons gave marked differences with respect to protein; 7 out of 10 showed large differences in calcium, and 6 out of 10 in phosphorus. The percentage of calcium appears to bear an inverse relationship to protein in the five grasses, while phosphorus bears no definite relationship. The fact is stressed that the specific relationships found between the five species should be considered as true only for the conditions of the experiment.

Season produced a distinct trend in all three constituents, the highest values being reached during the cool winter months. Protein varies directly with calcium as well as phosphorus throughout the season. It should be noted that in the present instance only fresh growth was taken for analysis.

Uncontrolled factors make it impossible to correlate the differences in chemical composition of grasses from the four sections with actual pasture management. Records of the ranch show that the section with the lowest phosphorus content gives no evidence of mineral deficiency.

LITERATURE CITED

- (1) ARCHIBALD, J. G., and BENNETT, E.
1933. CHEMICAL COMPOSITION OF HERBAGE FROM MASSACHUSETTS PASTURES. Mass. Agr. Expt. Sta. Bul. 300, 7pp.
- (2) ASTON, B. C. et al.
1931. MINERAL CONTENT OF PASTURES RESEARCH. New Zealand Jour. of Agr., Vol. 42, No. 4, pp. 226-230.
- (3) BECKER, R. B., NEAL, W. M., and SHEALY, A. L.
1933. STIFFS OR SWEENEY (PHOSPHORUS DEFICIENCY) IN CATTLE. Fla. Agr. Expt. Sta. Bul. 264, 27 pp., illus.
- (4) _____
1931. I. SALT SICK: ITS CAUSE AND PREVENTION. II. MINERAL SUPPLEMENTS FOR CATTLE. Fla. Agr. Expt. Sta. Bul. 231, 23 pp., illus.
- (5) BROWN, B. A.
1933. PASTURE INVESTIGATIONS (FIFTH REPORT), A RESUME OF THIRTEEN YEARS OF RESEARCH. Storrs Agr. Expt. Sta. Bul. 190, 15 pp., illus.
- (6) BRYMNOR, THOMAS and ELLIOTT, F. J.
1932. ON THE YIELDS AND COMPOSITION OF PASTURE GRASS FROM THE TREE FIELD PLOTS AT COCKLE PARK. Jour. of Agr. Sci., Vol. 22, pt. 4, pp. 736-754.
- (7) COOK, L. J.
1933. RESUME OF 12 YEARS PASTURE EXPERIMENTAL WORK AT KYBYBOLITE. Jour. of Dept. of Agr. of South Aust., Vol. 37, pp. 248-260.
- (8) ECKLES, C. H., GULLICKSON, T. W., and PALMER, L. S.
1932. PHOSPHORUS DEFICIENCY IN THE RATONS OF CATTLE. Minn. Agr. Expt. Sta. Tech. Bul. 91, 118 pp., illus.
- (9) ENLOW, C. R., and COLEMAN, J. M.
1929. INCREASING THE PROTEIN CONTENT OF PASTURE GRASSES BY FREQUENT LIGHT APPLICATIONS OF NITROGEN. Jour. Amer. Soc. Agron., Vol. 21, pp. 845-853.
- (10) FAGAN, T. W., MILTON, W. E. J., and PROVAN, A. L.
1928. THE EFFECT OF NITRATE OF SODA ON THE YIELD AND CHEMICAL COMPOSITION OF A SIMPLE SEEDS MIXTURE IN THE FIRST HARVEST YEAR. Welsh Plant-Breeding Sta. Series H, No. 9, Seasons, 1926-27, 27 pp.
- (11) FAGAN, T. W.
1928. FACTORS THAT INFLUENCE THE CHEMICAL COMPOSITION OF HAY. Welsh Jour. of Agr., Vol. 4, pp. 92-102.
- (12) GRUNDER, MAYNARD S.
1933. YIELD AND CHEMICAL COMPOSITION OF CERTAIN PASTURE CROPS, FERTILIZED AND UNFERTILIZED. Jour. Agr. Res. 46, pp. 375-386.
- (13) HANSON, H. C., LOVE, L. D., and MORRIS, M. S.
1931. EFFECTS OF DIFFERENT SYSTEMS OF GRAZING BY CATTLE UPON A WESTERN WHEAT-GRASS TYPE OF RANGE. Colorado Agr. Expt. Sta. Bul. 377, 82 pp., illus.
- (14) HOGAN, A. G.
1933. THE FEEDING OF LIVESTOCK. Mo. Agr. Expt. Sta. Bul. 330, 36 pp., illus.
- (15) HOPPER, T. H., and NESBITT, L. L.
1930. THE COMPOSITION OF SOME NORTH DAKOTA PASTURE AND HAY GRASSES. N. Dak. Agr. Expt. Sta. Bul. 236, 39 pp.
- (16) HUDSON, A. W., and McPHERSON, G. K.
1933. INVESTIGATIONS IN PASTURE PRODUCTION. New Zealand Jour. of Agr., Vol. 47, No. 4, pp. 238-242.
- (17) HUDSON, A. W.
1931. INVESTIGATIONS IN PASTURE PRODUCTION. New Zealand Jour. of Agr., Vol. 43, No. 2, pp. 77-95.

- (18) HUDSON, A. W., et al.
1930. PASTURE TOPDRESSING IN CANTERBURY. PART II—OBSERVATIONAL EXPERIMENTS WITH LIME, PHOSPHATE, POTASH, AND NITROGEN, 1928-29 and 1929-30. *New Zealand Jour. of Agr.*, Vol. 41, No. 5, pp. 326-352, illus.
- (19) HUFFMAN, C. F., DUNCAN, C. W., ROBINSON, C. S., and LAMB, L. W.
1933. PHOSPHORUS REQUIREMENT OF DAIRY CATTLE WHEN ALFALFA FURNISHES THE PRINCIPAL SOURCE OF PROTEIN. *Mich. Agr. Expt. Sta. Tech. Bul.* 134, 75 pp., illus.
- (20) LANTOW, J. L.
1933. THE ASSIMILATIONS OF CALCIUM AND PHOSPHORUS FROM DIFFERENT MINERAL COMPOUNDS AND THEIR EFFECT ON RANGE CATTLE. *New Mex. Agr. Expt. Sta. Bul.* 214, 30 pp., illus.
- (21) LOVE, H. H.
1924. A MODIFICATION OF STUDENT'S TABLE FOR USE IN INTERPRETING EXPERIMENTAL RESULTS. *Jour. Amer. Soc. Agron.*, Vol. 16, No. 1, pp. 68-73.
- (22) MCCREARY, OTTO
1927. WYOMING FORAGE PLANTS AND THEIR CHEMICAL COMPOSITION—STUDIES NO. 8. *Wyom. Agr. Expt. Sta. Bul.* 157, pp. 91-106.
- (23) MITCHELL, H. H.
1933. THE FEEDING OF MINERAL SUPPLEMENTS TO LIVESTOCK. III. *Agr. Expt. Sta. Circ.* 411, 8 pp.
- (24) NEWLANDER, J. A., JONES, C. H., and ELLENBERGER, H. B.
1933. CHEMICAL COMPOSITION OF PASTURE GRASSES IN VERMONT. *Vermont Agr. Expt. Sta. Bul.* 362, 19 pp.
- (25) NOWOSAD, F. S.
1933. THE EFFECT OF SOME COMMERCIAL FERTILIZERS ON THE BOTANICAL COMPOSITION AND YIELD OF PERMANENT PASTURES. *Scientific Agr. (La Revue Agronomique Canadienne)*, Vol. 14, pp. 57-69.
- (26) ORR, J. B.
1929. MINERALS IN PASTURES AND THEIR RELATION TO ANIMAL NUTRITION. H. K. Lewis & Co., Ltd., 150 pp. London.
- (27) RICHARDSON, A. E. V., TRUMBLE, H. C., and SHAPTER, R. E.
1932. THE INFLUENCE OF GROWTH STAGE AND FREQUENCY OF CUTTING ON THE YIELD AND COMPOSITION OF A PERENNIAL GRASS—*PHALARIS TUBEROSA*. Council for Scientific and Indus. Res., Commonwealth of Aust. Bul. 66, 35 pp., illus.
- (28) RIPPERTON, J. C., GOFF, R. A., EDWARDS, D. W., and DAVIES, W. C.
1933. RANGE GRASSES OF HAWAII. *Hawaii Agr. Expt. Sta. Bul.* 65, 58 pp., illus.
- (29) SHUTT, F. T., HAMILTON, S. N., and SELWYN, N. H.
1930. THE PROTEIN CONTENT OF GRASS, CHIEFLY MEADOW FOXTAIL (*ALOPECURUS PRATENSIS*), AS INFLUENCED BY FREQUENCY OF CUTTING. *Jour. Agr. Sci. (England)*, Vol. 20, pp. 120-134, illus.
- (30) STAPLEDON, R. G., and HANLEY, J. A.
1927. GRASSLAND: ITS MANAGEMENT AND IMPROVEMENT. Oxford at The Clarendon Press, Great Britain, 159 pp.
- (31) WILSIE, C. P., and TAKAHASHI, M.
1934. NAPIER GRASS (*PENNISETUM PURPUREUM*): A PASTURE AND GREEN FODDER CROP FOR HAWAII. *Hawaii Agr. Expt. Sta. Bul.* 72, 17 pp.
- (32) WOODMAN, H. E., BLUNT, D. L., and STEWART, JAMES
1926. NUTRITIVE VALUE OF PASTURES. *Jour. Agr. Science*, Vol. 16, Pt. 2, pp. 205-274.
- (33) WOODMAN, H. E., and UNDERWOOD, E. J.
1932. NUTRITIVE VALUE OF PASTURE. VIII. THE INFLUENCE OF INTENSIVE FERTILIZING ON THE YIELD AND COMPOSITION OF GOOD PERMANENT PASTURE. *Jour. of Agr. Science*, Vol. 22, Pt. 1, pp. 26-71.

APPENDIX

RHODES GRASS (CHLORIS GAYANA)

Sample number	Source of sample	Date of harvest	Percent Moisture (green basis)	Constituents expressed as percentages of dry matter			
				Crude Protein (Nx6.25)	Lime (CaO)	Phosphoric Acid (P_2O_5)	Silica-free ash
296	Waikii	Feb. '33	63.00	7.40	1.42	1.43	7.20
338	"	June, '33	67.00	7.02	.97	1.29	9.29
213	Dairy	Aug., '32	64.30	6.45	.79	.83	6.14
259	"	Dec., '32	62.30	8.40	1.09	.59	5.25
285	"	Feb., '33	76.50	8.97	.94	.56	4.28
323	"	Apr., '33	71.90	7.30	.89	1.11	6.76
340	"	June, '33	67.10	5.24	1.01	1.19	7.54
371	"	Aug., '33	60.80	9.07	1.02	1.06	7.53
193	Kaala	Aug., '32	84.30	13.79	.70	.54	8.38
229	"	Oct., '32	72.40	7.55	.61	.30	5.43
252	"	Dec., '32	79.40	9.55	.84	.42	6.89
277	"	Feb., '33	74.50	12.80	1.19	.52	7.00
306	"	Apr., '33	75.60	8.34	.91	.43	6.27
353	"	June, '33	73.40	6.55	.77	.51	5.97
359	"	Aug., '33	76.40	8.66	.68	.52	5.75
211	Keamoku	Aug., '32	71.30	9.46	1.09	.16	6.13
248	"	Oct., '32	74.30	11.10	1.03	.27	7.23
266	"	Dec., '32	78.80	9.82	1.03	.35	7.19
299	"	Feb., '33	76.70	9.08	1.19	.37	7.61

TALL FESCUE (FESTUCA ELATIOR)

Sample number	Source of sample	Date of harvest	Percent Moisture (green basis)	Constituents expressed as percentages of dry matter			
				Crude Protein (Nx6.25)	Lime (CaO)	Phosphoric Acid (P_2O_5)	Silica-free ash
203	Waikii	Aug., '32	79.80	12.16	.91	.98	11.12
240	"	Oct., '32	74.60	12.50	1.06	.86	11.78
272	"	Dec., '32	80.50	15.20	1.07	1.22	12.69
295	"	Feb., '33	80.00	14.10	1.14	1.55	12.57
313	"	Apr., '33	80.30	12.20	1.11	1.25	13.43
336	"	June, '33	67.80	6.18	.52	.74	8.07
217	Dairy	Aug., '32	77.30	8.77	.74	.44	10.43
236	"	Oct., '32	66.80	10.20	.98	.43	10.64
261	"	Dec., '32	80.30	14.50	1.13	.80	12.46
287	"	Feb., '33	79.20	17.80	1.02	.78	11.38
325	"	Apr., '33	84.00	11.20	.72	.83	12.98
346	"	June, '33	71.40	7.11	.76	.60	9.74
367	"	Aug., '33	71.60	11.75	.85	.81	11.40
195	Kaala	Aug., '32	80.90	11.53	.39	.63	8.54
230	"	Oct., '32	72.00	8.90	.42	.25	6.87
253	"	Dec., '32	82.40	13.10	.72	.44	9.11
279	"	Feb., '33	79.40	15.40	.63	.53	9.41
307	"	Apr., '33	81.80	9.35	.50	.33	9.00
348	"	June, '33	74.50	10.35	.61	.33	7.78
360	"	Aug., '33	71.30	9.96	.51	.35	6.66
209	Keamoku	Aug., '32	69.80	12.47	.98	.21	8.53
246	"	Oct., '32	74.20	16.70	.97	.34	10.62
268	"	Dec., '32	81.00	16.00	.96	.41	12.33
301	"	Feb., '33	78.80	15.50	1.04	.44	9.94
320	"	Apr., '33		12.90	1.07	.34	11.28

PASPALUM (PASPALUM DILATATUM)

Sample number	Source of sample	Date of harvest	Percent Moisture (green basis)	Constituents expressed as percentages of dry matter			
				Crude Protein (Nx6.25)	Lime (CaO)	Phosphoric Acid (P ₂ O ₅)	Silica-free ash
199	Waikii	Aug., '32	74.60	9.42	.73	.69	6.60
239	"	Oct., '32	65.40	8.02	.86	.55	5.84
271	"	Dec., '32	70.20	8.80	1.23	.72	7.64
312	"	Apr., '33	72.70	10.60	1.90	.82	11.45
332	"	June, '33	67.60	7.78	1.25	.54	8.01
218	Dairy	Aug., '32	74.00	8.47	.69	.48	6.68
237	"	Oct., '32	68.00	8.07	1.04	.34	6.70
260	"	Dec., '32	63.70	10.70	1.21	.53	7.45
286	"	Feb., '33	70.80	16.25	1.10	.71	6.63
324	"	Apr., '33	78.20	13.30	1.04	.76	9.69
341	"	June, '33	69.30	7.90	.90	.51	7.65
365	"	Aug., '33	58.00	8.33	1.02	.50	6.76
194	Kaala	Aug., '32	81.00	17.09	.72	.57	6.47
228	"	Oct., '32	74.50	11.60	.75	.40	5.10
251	"	Dec., '32	81.60	12.65	.83	.53	6.64
278	"	Feb., '33	74.10	15.40	.95	.58	6.22
305	"	Apr., '33	79.70	11.50	.94	.44	13.43
354	"	June, '33	75.50	10.25	.79	.51	6.18
358	"	Aug., '33	75.40	10.32	.68	.43	5.00
207	Keamoku	Aug., '32	67.00	5.58	.61	.14	5.46
244	"	Oct., '32	71.00	10.70	.69	.27	6.15
267	"	Dec., '32	77.60	12.70	.94	.33	9.74
300	"	Feb., '33	71.90	13.20	.89	.36	7.43
319	"	Apr., '33	74.10	12.25	1.03	.29	8.84

KIKUYU (PENNISETUM CLANDESTINUM)

Sample number	Source of sample	Date of harvest	Percent Moisture (green basis)	Constituents expressed as percentages of dry matter			
				Crude Protein (Nx6.25)	Lime (CaO)	Phosphoric Acid (P_2O_5)	Silica-free ash
201	Waikii	Aug., '32	75.50	8.12	.98	1.32	8.60
238	"	Oct., '32	66.40	9.00	1.17	1.06	8.80
270	"	Dec., '32	78.90	14.25	1.09	1.38	10.41
294	"	Feb., '33	72.50	9.60	1.29	1.47	8.90
311	"	Apr., '33		10.35	1.18	1.46	10.89
333	"	June, '33	60.20	7.23	1.01	1.00	8.95
216	Dairy	Aug., '32	77.70	9.76	1.02	.85	8.75
235	"	Oct., '32	66.70	10.85	1.27	.87	8.12
257	"	Dec., '32	81.60	17.30	1.05	1.02	12.40
284	"	Feb., '33	77.80	14.30	1.20	.75	9.57
321	"	Apr., '33	79.30	10.50	1.00	.95	10.03
339	"	June, '33	78.30	7.49	1.05	.86	9.59
368	"	Aug., '33	69.40	8.70	.89	.90	8.47
189	Kaala	Aug., '32	83.50	7.96	.71	.51	7.49
226	"	Oct., '32	76.40	8.37	.67	.46	4.96
249	"	Dec., '32	77.70	10.45	.62	.61	6.24
276	"	Feb., '33	81.90	7.58	.73	.46	5.18
303	"	Apr., '33	81.70	6.89	.68	.52	5.47
352	"	June, '33	73.80	7.58	.71	.61	6.71
356	"	Aug., '33	76.80	9.00	.62	.44	5.47
210	Keamoku	Aug., '32	71.50	11.64	1.33	.25	7.46
247	"	Oct., '32	74.40	12.30	1.03	.35	7.87
265	"	Dec., '32	80.10	10.45	.91	.46	8.94
298	"	Feb., '33	72.50	8.73	1.11	.35	7.12
318	"	Apr., '33		7.40	1.26	.30	7.04

PHALARIS TUBEROSA

Sample number	Source of sample	Date of harvest	Percent Moisture (green basis)	Constituents expressed as percentages of dry matter			
				Crude Protein (N $\times$ 6.25)	Lime (CaO)	Phosphoric Acid (P $_2$ O $_5$)	Silica-free ash
200	Waikii	Aug., '32	79.00	13.09	.83	1.02	10.69
241		Oct., '32	73.20	15.60	.98	.92	11.90
273		Dec., '32	81.60	19.00	1.08	1.25	13.95
292		Feb., '33	81.30	16.23	1.08	1.52	13.94
314		Apr., '33	80.20	13.25	1.13	1.44	14.13
337	Dairy	June, '33	59.10	7.05	.52	.61	8.20
212		Aug., '32	78.20	10.01	.68	.70	10.48
262		Dec., '32	77.00	16.15	1.23	.91	12.18
288		Feb., '33	82.60	21.15	1.09	.97	11.65
326		Apr., '33	85.30	15.70	.72	.79	12.80
347	Kaala	June, '33	73.70	9.31	.84	.73	10.59
372		Aug., '33	77.10	14.60	.83	1.01	15.01
196		Aug., '32	85.50	13.94	.36	.58	11.73
232		Oct., '32	76.80	11.15	.34	.43	9.64
255		Dec., '32	87.80	16.00	.34	.69	11.63
280	Keamoku	Feb., '33	82.70	17.00	.43	.62	10.23
310		Apr., '33	83.00	13.80	.40	.46	10.82
349		June, '33	79.70	11.00	.41	.50	10.13
362		Aug., '33	75.00	13.35	.45	.40	9.14
208		Aug., '32	64.80	10.61	1.00	.28	12.50
245	"	Oct., '32	77.70	15.20	.82	.46	14.43
269		Dec., '32	84.50	14.90	1.09	.47	19.32
302		Feb., '33	80.00	17.60	.79	.48	11.97

